AMD Athlon™ Processor Thermal Solution

Application Note

Publication # **22439** Rev: **E**
Issue Date: **February 2000**

Contents

List of Figures

List of Tables

Revision History

Date	Rev	Description
February 2000	E	Added the 850-MHz AMD Athlon processor to Table 1, “Package Thermal Specification (Model 1 and Model 2),” on page 1.
January 2000	D	Added the 800-MHz AMD Athlon processor to Table 1, “Package Thermal Specification (Model 1 and Model 2),” on page 1. Revised the maximum thermal power values for all Model 2 processors in Table 1, “Package Thermal Specification (Model 1 and Model 2),” on page 1.
December 1999	C	Added information about the AMD Athlon processor Model 1 and Model 2 to “Introduction” on page 1. Added the 750 MHz AMD Athlon processor to Table 1, “Package Thermal Specification (Model 1 and Model 2),” on page 1.
October 1999	B	Added the 700 MHz AMD Athlon™ processor to Table 1, “Package Thermal Specification,” on page 1.
August 1999	A	Initial release.

Application Note

AMD Athlon™ Processor Thermal Solution

Introduction

The AMD Athlon™ processor operating specification calls for the plate temperature (T_{plate}) to be in the range of 0°C to 70°C. The ambient temperature (T_A) is not specified as long as the plate temperature is not violated. The plate temperature must be measured on the center of the package.

Table 1 shows the AMD Athlon processor Model 1 and Model 2 thermal specifications. Model 1 refers to the AMD Athlon manufactured with 0.25-micron process technology and Model 2 refers to the AMD Athlon processor manufactured with 0.18-micron process technology.

Table 1. Package Thermal Specification (Model 1 and Model 2)

	Maximum Thermal Power							
	500 MHz	**550 MHz**	**600 MHz**	**650 MHz**	**700 MHz**	**750 MHz**	**800 MHz**	**850 MHz**
Model 1	42 W	46 W	50 W	54 W	50 W	n/a	n/a	n/a
Model 2	n/a	31 W	34 W	36 W	39 W	40 W	48 W	50 W

Note:
The T_{plate} Plate Temperature is 0°C–70°C for all processors listed in this table.

An effective thermal management system is the best way to maintain the plate temperature within specification. In addition to the thermal characteristics and power dissipation of the processor, the temperature of the processor plate is dependent on ambient temperature and air velocity local to the processor. The internal ambient temperature is affected by several variables—power dissipated by electronic components and peripherals, airflow of the chassis, and external ambient temperature.

Thermal management consists of the use of heatsinks, thermal interface materials, heatsink mounting mechanisms, fans, chassis ventilation, and component placement. This application note is intended to guide the system designer through the process of developing an effective thermal solution for the AMD Athlon processor.

System Conditions

AMD's test procedures for heatsink validation tests to an external ambient of 37ºC. Many PC chassis/system boxes result in an internal 10°C increase in temperature over the external ambient temperature. With proper ventilation, a chassis can typically have an increase of temperature from external ambient to internal ambient of approximately 5ºC. In general, this means the thermal solution should be designed to allow a local internal ambient (T_A) of 42°C – AMD's target internal ambient temperature.

Thermal Solutions

Heatsink

Figure 1 shows the thermal model of a processor with a passive thermal solution. The plate temperature (T_{Plate}) can be calculated from the following equation:

$$T_P = T_A + P_{MAX} \cdot \theta_{PA}$$
$$= T_A + P_{MAX} \cdot (\theta_{PS} + \theta_{SA})$$

Where:

P_{MAX} = Maximum Power Consumption
θ_{PA} = Plate-to-Ambient Thermal Resistance
θ_{PS} = Interface Material Thermal Resistance
θ_{SA} = Sink-to-Ambient Thermal Resistance
T_A = Local Ambient Temperature

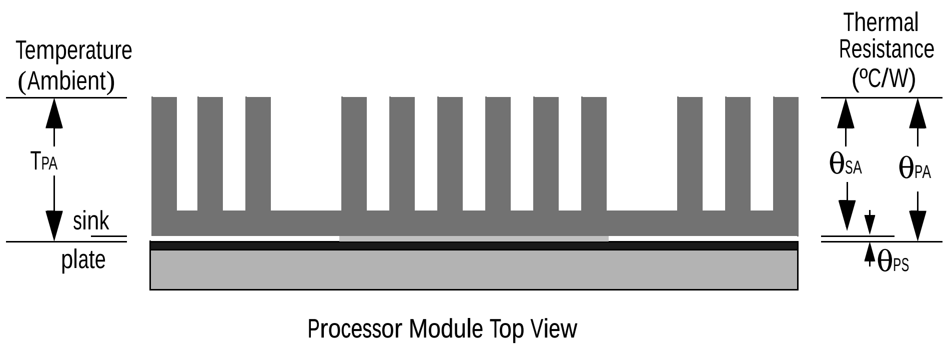

Figure 1. Thermal Model

Figure 2 shows the plate temperature (T_{PA}) in relation to the power consumption (X-axis) and the thermal resistance (Y-axis). If the power consumption and plate temperature are known, the thermal resistance (θ_{PA}) requirement can be calculated for a given ambient temperature (T_A) value.

The thermal resistance of a heatsink is determined by the heat dissipation surface area, the material and shape of the heatsink, and the airflow volume across the heatsink. In general, the larger the surface area the lower the thermal resistance.

The required thermal resistance of a heatsink (θ_{SA}) can be calculated using the following example:

If:

T_{plate} = 70°C
T_A = 42°C
P_{MAX} = 50W at 600MHz

Then:

$$\theta_{PA} \le \left(\frac{T_{plate} - T_A}{P_{MAX}}\right) = \frac{28°C}{50W} = 0.56\ (°C/W)$$

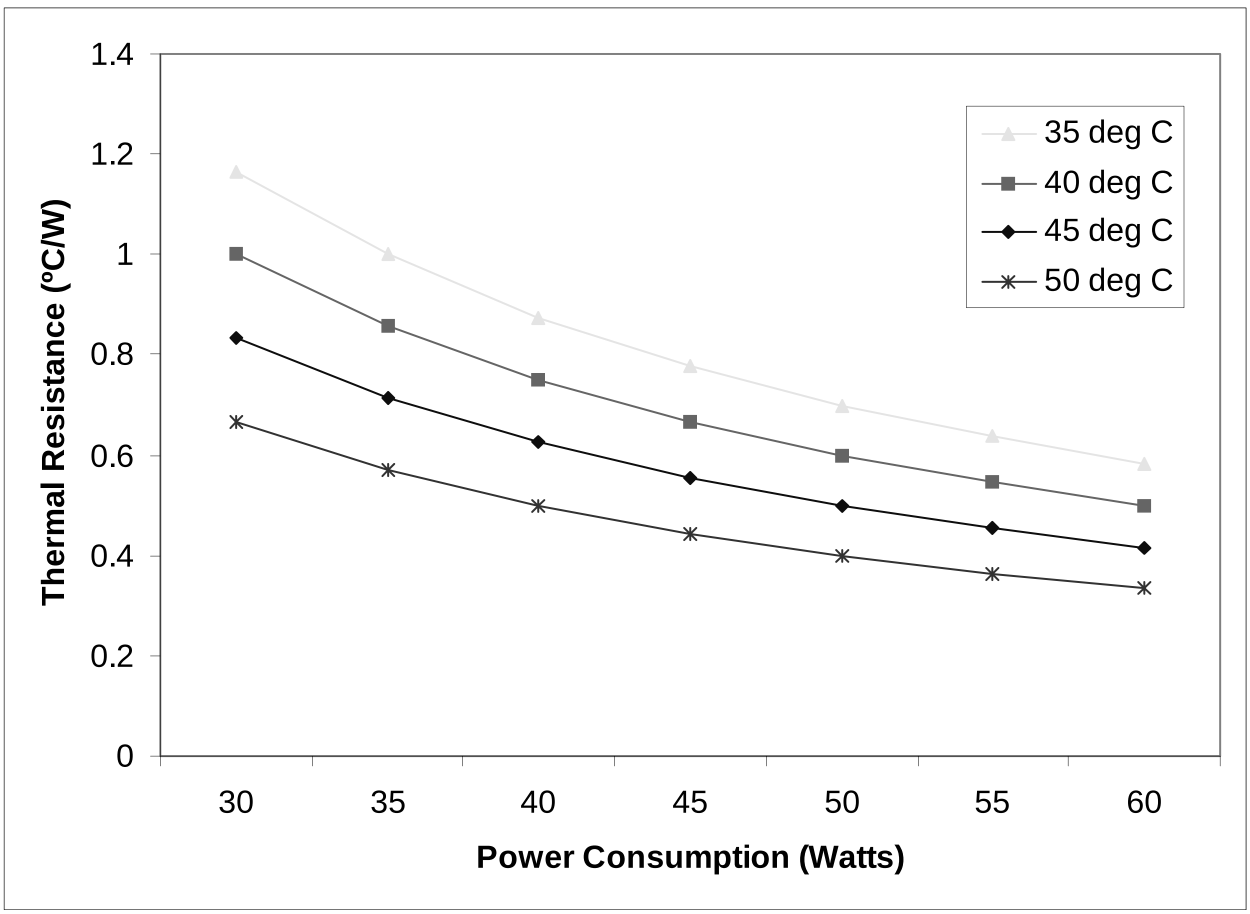

Figure 2. Power Consumption versus Thermal Resistance

Interface Materials

The interface material used between the heatsink and processor is important. The purpose of this material is to fill any microscopic air gaps and ensure a thermally efficient path is established for heat to flow from the package into the heatsink. There are several different types of thermally conductive interface material in use today. The most common are grease, wax, thermal pads/tapes, and epoxy. While dry interfaces (pads and tapes) are often the easiest to use, they have the poorest thermal resistance. They are not recommended because small pockets of air can be trapped during installation. Wet or paste interfaces (grease, gel, wax, and epoxy) have lower thermal resistances.

Although epoxy, when handled correctly, can provide a reasonable thermal interface, it is not a reliable mechanical attachment. Caution should also be taken with pre-applied waxes, because pockets of air (a poor thermal conductor) can be trapped beneath the heatsink during assembly. AMD recommends the use of grease and gels as thermal interfaces. These materials are able to maintain the lowest thermal resistance more consistently. High performance grease, such as Shinetsu G749/G750, have a thermal resistance of approximately 0.10°C/W. In general, these materials can achieve a thermal resistance of 0.10 to 0.20°C/W.

The application of interface material, in addition to material type, is also important. Its purpose is simply to fill microscopic air gaps and enable a thermally efficient path for heat transfer. Only a thin layer of interface material is desired between the heatsink and processor. Excessive amounts of interface material may cause the interface to be thicker; therefore, increasing the thermal resistance and thereby making the thermal solution less effective.

Thermal grease is recommended as interface material because it provides the lowest thermal resistance (≅ 0.10°C/W). The required thermal resistance (θ_{SA}) of the heatsink in this example is calculated as follows:

$$\theta_{SA} = \theta_{PA} - \theta_{PS} = 0.56 - 0.10 = 0.46\ (°C/W)$$

For manufacturing reliability, thermal wax or phase change interface is usually preferred due to ease of installation and its excellent thermal characteristics. High performance phase change interfaces, such as Berquist 200U, Chomerics T443, or Furon C1055, have a thermal resistance of approximately 0.16°C/W.

Heat Dissipation Path

Figure 3 shows the heat dissipation path of the processor. Due to the lower thermal resistance between the processor die junction and plate, most of the heat generated by the processor is transferred from the top surface of the plate.

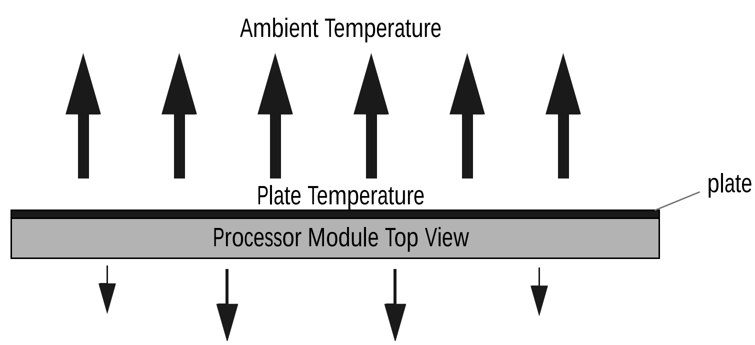

Figure 3. Processor Module Heat Dissipation Path

Measuring Plate Temperature

The processor module plate temperature is measured to ensure that the thermal solution meets the operational specification of the processor. This temperature should be measured on the center of the package, where most of the heat is dissipated. Figure 4 shows the correct location for measuring the plate temperature. If a heatsink is installed while measuring, the thermocouple must be installed into the heatsink by way of a small hole drilled through the heatsink base (for example, 1/16 of an inch). The thermocouple is then attached to the base of the heatsink and the small hole is filled using thermal epoxy, allowing the tip of the thermocouple to touch the center of the module plate.

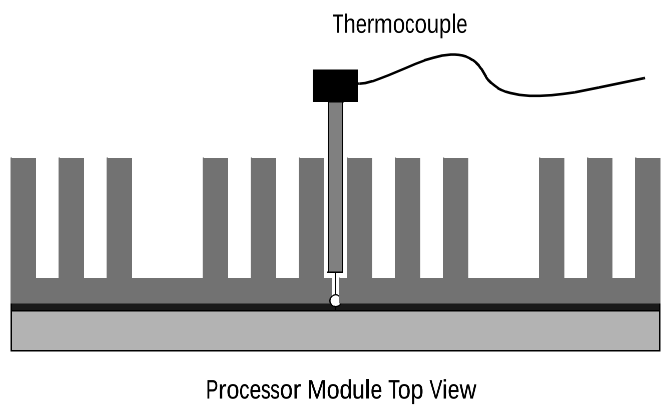

Figure 4. Measuring Plate Temperature

Layout and Airflow Considerations

Airflow Management in a System Design

Complete airflow management in a system is important. In addition to the volume of air, the path of the air is also important. A processor module power supply with a voltage regulator is required to support the lower voltage to the module. Because the voltage regulator is designed with power transistors, system airflow management should dissipate the heat from the power transistors in conjunction with the heat from the processor module.

Figure 5 shows the airflow management in a system using the ATX form-factor. The orientation of the power supply fan and the motherboard are modified in the ATX platform design. The system power supply fan pulls cool air through the chassis and across the processor module. The module is located near the system power supply fan, where it can receive adequate airflow. In addition, this airflow also provides adequate heat dissipation to the power supply of the processor module. The arrangement significantly improves the airflow across the processor module with minimum installation cost.

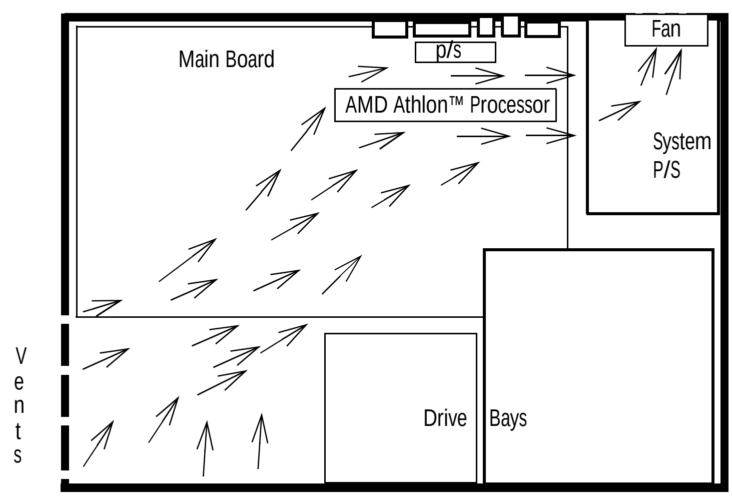

Figure 5. Airflow Path in an ATX Form-Factor System